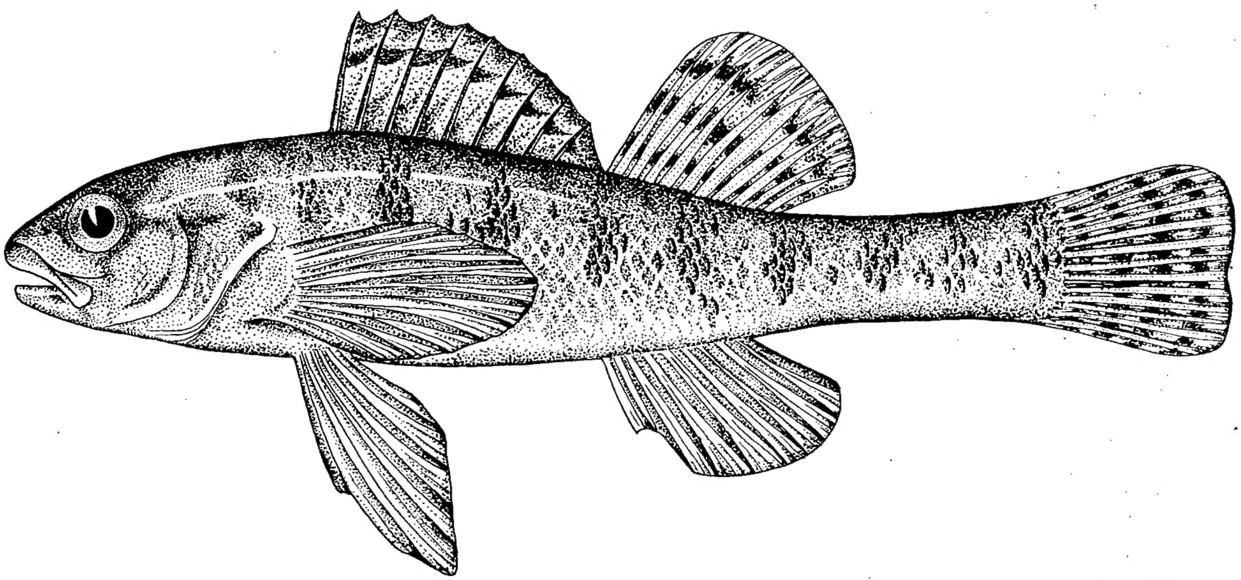
Biological Services Program

FWS/OBS-82/10.9
FEBRUARY 1982

HABITAT SUITABILITY INDEX MODELS: SLOUGH DARTER



Fish and Wildlife Service

U.S. Department of the Interior

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February 1982

HABITAT SUITABILITY INDEX MODELS: SLOUGH DARTER

by

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PREFACE

The habitat use information and Habitat Suitability Index (HSI) models presented in this document are an aid for impact assessment and habitat management activities. Literature concerning a species' habitat requirements and preferences is reviewed and then synthesized into HSI models, which are scaled to produce an index between 0 (unsuitable habitat) and 1 (optimal habitat). Assumptions used to transform habitat use information into these mathematical models are noted, and guidelines for model application are described. Any models found in the literature which may also be used to calculate an HSI are cited, and simplified HSI models, based on what the authors believe to be the most important habitat characteristics for this species, are presented.

Use of the models presented in this publication for impact assessment requires the setting of clear study objectives and may require modification of the models to meet those objectives. Methods for reducing model complexity and recommended measurement techniques for model variables are presented in Appendix A.

The HSI models presented herein are complex hypotheses of species-habitat relationships, <u>not</u> statements of proven cause and effect relationships. Results of model performance tests, when available, are referenced; however, models that have demonstrated reliability in specific situations may prove unreliable in others. For this reason, the FWS encourages model users to convey comments and suggestions that may help us increase the utility and effectiveness of this habitat-based approach to fish and wildlife planning. Please send comments to:

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CONTENTS

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SLOUGH DARTER (Etheostoma gracile)

HABITAT USE INFORMATION

General

The native range of the slough darter (*Etheostoma gracile*) extends from western Alabama (Smith-Vaniz 1968) to central Texas and northward in the lowland areas of the former Mississippi Embayment and the Interior Low Plateau to central Illinois (Collette 1962) and southwestern Indiana (Gerking 1945). Its distribution also includes southeast Kansas (Metcalf 1959; Cross 1967) and northeast Oklahoma (Blair 1959). Natural hybridization with the blackside darter (*Percina maculata*) has been recorded (Page 1976).

Age, Growth, and Food

Slough darters mature at age I and reach a maximum standard length of 48 mm at age IV (Braasch and Smith 1967). Slough darters are primarily bottom feeders and feed throughout the year on insect larvae, microcrustaceans, and some snails (Braasch and Smith 1967). Fry eat diatoms and other plankton at first and, subsequently, insects and microcrustaceans (Braasch and Smith 1967).

Reproduction

The spawning season for slough darters extends from March to early June (Hubbs and Cannon 1935; Collette 1962; Braasch and Smith 1967; Cross 1967). The female slough darter lays eggs singly on objects, such as twigs or leaf petioles. In the laboratory, females spawned only once, and no postspawning care of the eggs was observed. Incubation was 5 days in the laboratory at 22.8° C, the temperature of the stream where the darters were collected (Braasch and Smith 1967). Spawning has not been observed in the field because of turbid conditions.

Specific Habitat Requirements

Adult. Slough darters are typically found in pools and oxbows of lowland streams (Gerking 1945; Cross 1955; Cook 1959; Braasch and Smith 1967; Cross 1967), in backwaters (Linder 1955; Collette 1962), bayous (Blatchley 1938; Hancock and Sublette 1958), sloughs (Cook 1959; Braasch and Smith 1967), swamps (Blatchley 1938; Gerking 1945; Collette 1962), and ponds or lakes (Cook 1959; Collette 1962). Optimal habitat for slough darters can be characterized as warm, turbid waters (Linder 1955; Wallen 1958; Braasch and Smith 1967; Pflieger 1975) with little or no flow (Gerking 1945; Cook 1959; Collette 1962; Cross 1967; Pflieger 1975), mud or silt bottoms (Hancock and Sublette 1958; Wallen 1958; Collette 1962; Braasch and Smith 1967), and some vegetation or debris (Braasch and Smith 1967). Vegetation may be used for cover and as a spawning substrate (Wallen 1958; Blair 1959; Braasch and Smith 1967; Cross 1967). However, Collette (1962) reported that only about half of the areas where slough darters were collected had aquatic vegetation, and the amount was usually slight to moderate. The most consistent habitat characteristic where

slough darters were collected was a mud or silt bottom (Collette 1962; Braasch and Smith 1967). Occasionally they were found over bedrock or clay (Wallen 1958; Collette 1962) and, somewhat more frequently, over sand, detritus, or gravel (Collette 1962). In rivers and streams, adults may overwinter in deep sand or mud bottomed pools (Braasch and Smith 1967).

Most slough darters were collected in waters with gradients of less than 0.5 m/km; they avoided areas with gradients averaging 3.5 m/km or more (Collette 1962). Within these lowland areas, pools are occupied almost exclusively (Hancock and Sublette 1958; Braasch and Smith 1967; Cross 1967). Thus, it is assumed that a high pool to riffle ratio is optimum. Sluggish (Gerking 1945; Hancock and Sublette 1958; Blair 1959) or quiet (≤ 10 cm/sec) (Wallen 1958; Braasch and Smith 1967) water is preferred. Slough darters are not found in upstream areas with current-swept channels (Collette 1962; Cross 1967).

In addition to current velocity, turbidity seems to be an important limiting factor (Collette 1962). Slough darters typically inhabit moderate (Gerking 1945; Linder 1955; Wallen 1958; Blair 1959; Collette 1962; Pflieger 1975) to highly turbid waters (Braasch and Smith 1967), although they may be found in clear or slightly turbid waters (Wallen 1958). Although upper turbidity limits are not known, it is assumed that very high turbidities adversely affect the population by limiting food production. Turbidity also provides cover for all life stages.

The pH tolerances of the slough darter have not been recorded. However, the species has been captured in a Louisiana bayou at a pH level of 6.7-7.2 (Hancock and Sublette 1958). A pH range of 6.5-8.5 is considered to be essential for good production of freshwater fish (Stroud 1967; U.S. Environmental Protection Agency 1972); a range of 5.5-9.5 provides only minimum protection for survival of freshwater fish (U.S. Environmental Protection Agency 1972).

There is little available data on either temperature or dissolved oxygen requirements of slough darters. The maximum temperature in a bayou where slough darters were collected one summer in Louisiana was 26.5° C (Hancock and Sublette 1958). Slough darters are subject to oxygen deficit kills when dissolved oxygen (D.O.) levels become too low (Braasch and Smith 1967). In a bayou having slough darters, the minimum D.O. concentration was 1.7 mg/l (Hancock and Sublette 1958). A D.O. value of 5.0 mg/l is an adequate lower limit to sustain optimum growth and survival of freshwater fish (Stroud 1967).

Embryo. Eggs hatch after 5 days at 22.8° C (Braasch and Smith 1967), and optimum temperature for embryos is considered similar.

Fry-Juvenile. No specific habitat requirement data for fry and juvenile slough darters are reported in the literature. However, since fry were caught in the same area as adults (Braasch and Smith 1967), we assume that the habitat requirements of fry and juveniles are the same or similar as for the adults.

HABITAT SUITABILITY INDEX (HSI) MODELS

Model Applicability

Geographic area. The model is applicable throughout the native range of the slough darter in North America. The standard of comparison for each individual variable suitability index is the optimum value of the variable that occurs anywhere within the range of the species.

Season. The model provides a rating for a water body based on its ability to support a reproducing population of slough darters through all seasons of the year.

Cover types. The model is applicable in riverine, palustrine, and lacustrine habitats as described by Cowardin et al. (1979).

Minimum habitat area. Minimum habitat area is defined as the minimum area of contiguous suitable habitat that is required for a species to live and reproduce. No attempt has been made to establish a minimum habitat size for slough darters.

Verification level. The acceptance goal of the slough darter model is to produce an index between 0 and 1 which has a positive relationship to habitat carrying capacity for slough darters. In order to verify that the model output was acceptable, HSI's were calculated from sample data sets. These sample data sets and their relationship to model verification are discussed in greater detail later.

Model Description - Riverine

Slough darter habitat quality analysis is based on basic components consisting of food, cover, water quality, and other various habitat requirements. Variables that have been shown to impact growth, survival, abundance, or other measures of well-being of slough darters are placed in the appropriate component (Figure 1).

Food-cover component. Information is lacking on the specific habitat requirements for food and cover in the slough darter. It is assumed that turbidity (V_6) is important because very high turbidities can limit the food supply. Turbidity can also provide cover for all life stages of the fish. Percent pools (V_2) is included because slough darters require pool habitat in a riverine habitat, and the food and cover requirements will be met in pool areas.

Water quality component. Dissolved oxygen (V_1) and average water temperature (V_5) are included because these parameters can affect survival, development, and growth of the species. Turbidity (V_6) is included because it is an important habitat characteristic limiting slough darters. pH (V_8) is an important water quality parameter that can affect survival of freshwater fish.

Other component. The variables in this component are those which aid in describing habitat suitability for the slough darter, yet are not specifically related to life requisite components already presented. Stream gradient (V_3) is included because slough darters are restricted to low gradient streams.

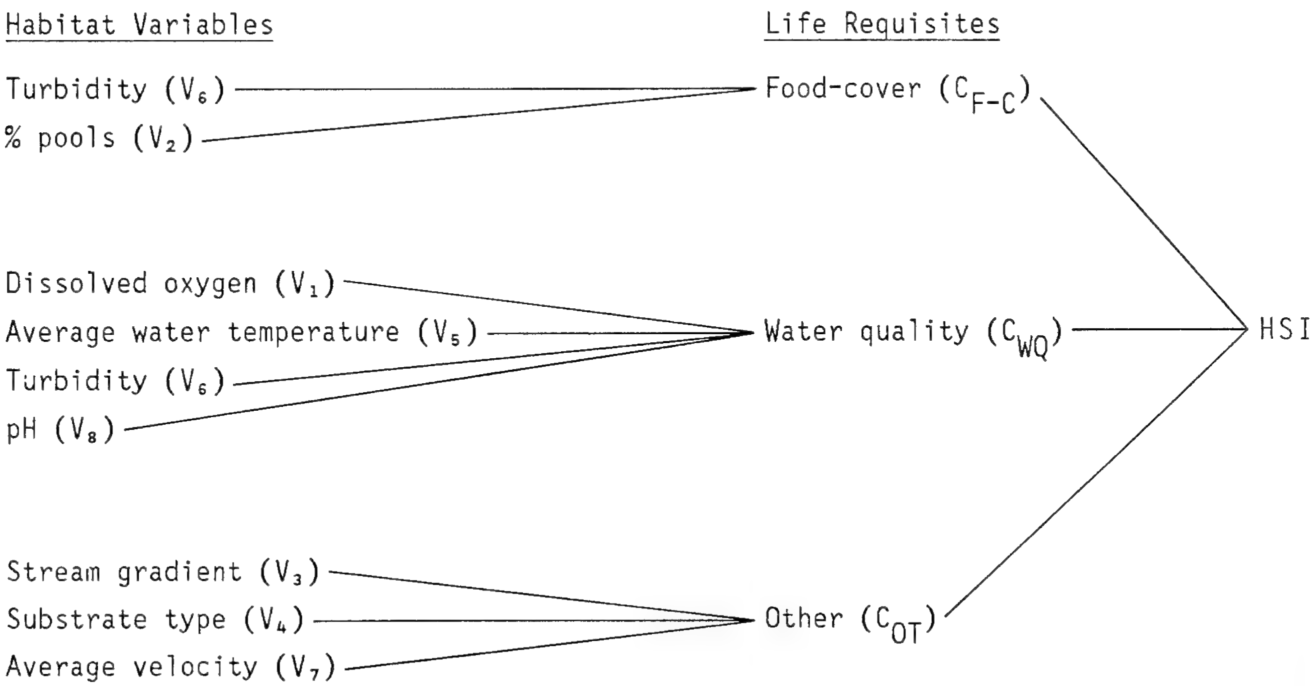


Figure 1. Tree diagram illustrating relationship of habitat variables and life requisites in the riverine model for the slough darter. The lacustrine model for this species includes the water quality component only.

Substrate type (V_4) is important because it is the most consistent habitat characteristic where slough darters are found. Average velocity (V_7) is included because slough darter distribution is limited by current velocity.

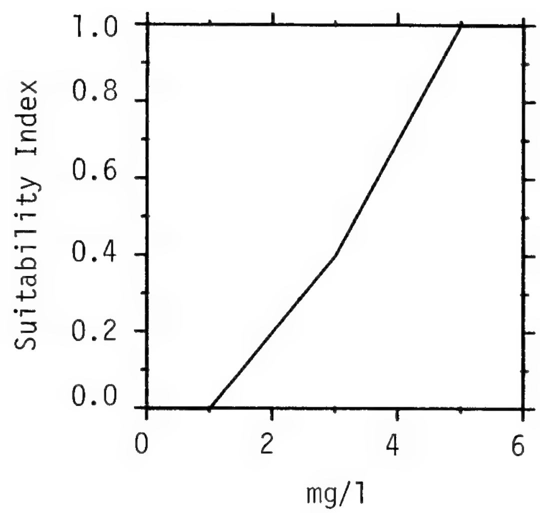
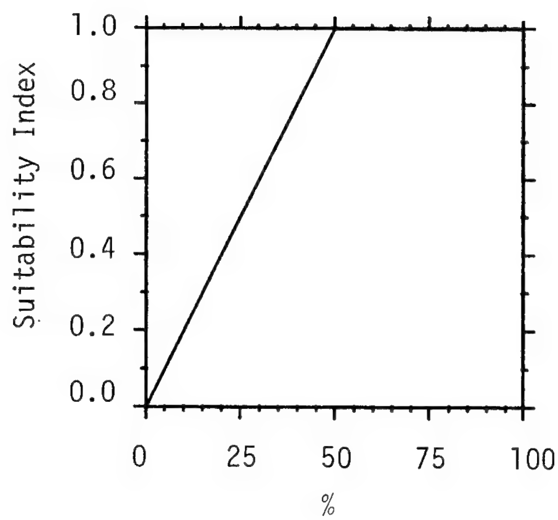
Model Description - Lacustrine

Because most information is limited to slough darter riverine habitats, the slough darter lacustrine model describes water quality only.

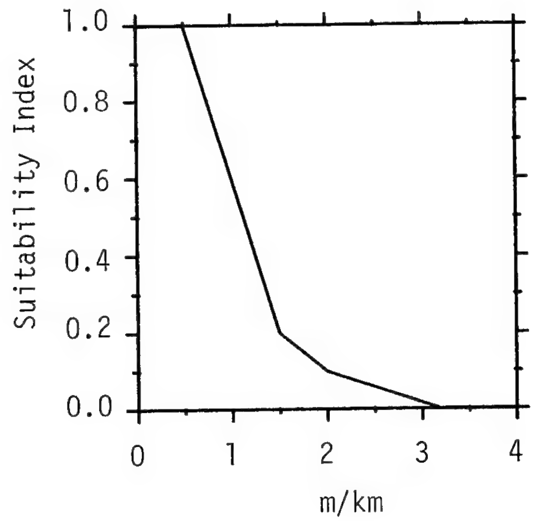
Water quality component. Refer to the riverine water quality component.

Suitability Index (SI) Graphs for Model Variables

This section contains suitability index graphs for the eight variables described above and equations for combining selected variable indices into a species HSI using the component approach. Variables may pertain to either a riverine (R) habitat, a lacustrine (L) habitat, or both.

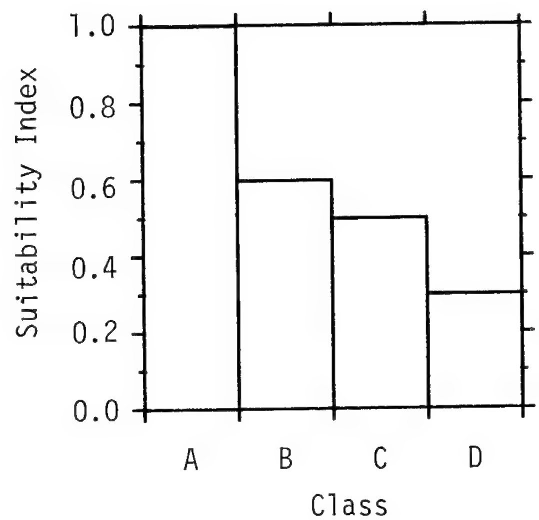
Habitat	Variable		Suitability Graph
R,L	(V_1)	Minimum dissolved oxygen level during the summer.	
R	(V_2)	Percent pools during average summer flow.	

R (V$_3$) Average stream gradient within the representative reach.

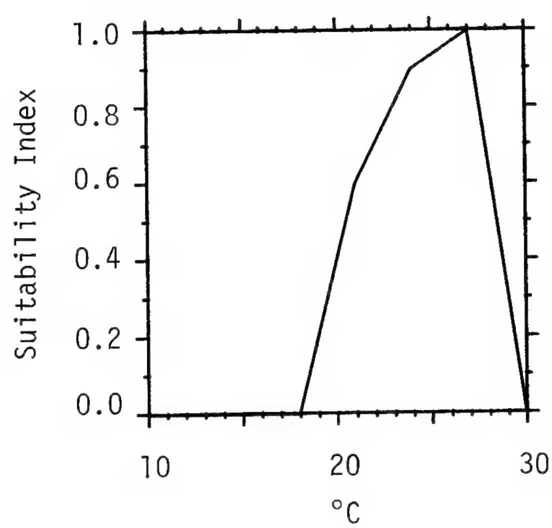


R (V$_4$) Dominant substrate type of a stream bottom.

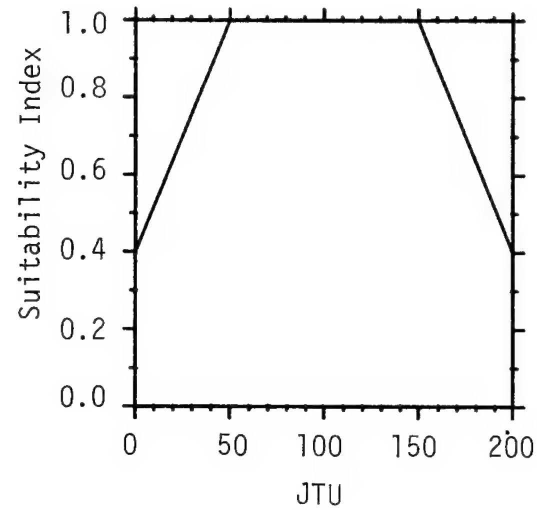
A) > 75% substrate mud or silt; some sand and/or detritus.
B) > 50% sand and/or detritus; some mud, silt, or gravel.
C) > 75% gravel, sand, or detritus.
D) Mostly clay and/or bedrock.



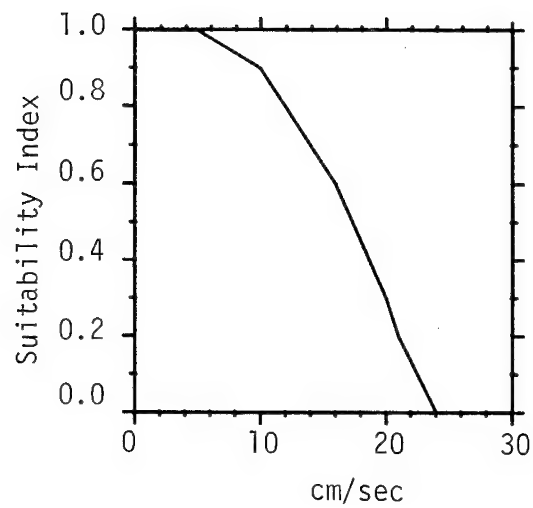
R,L (V$_5$) Average water temperature, spring to fall.



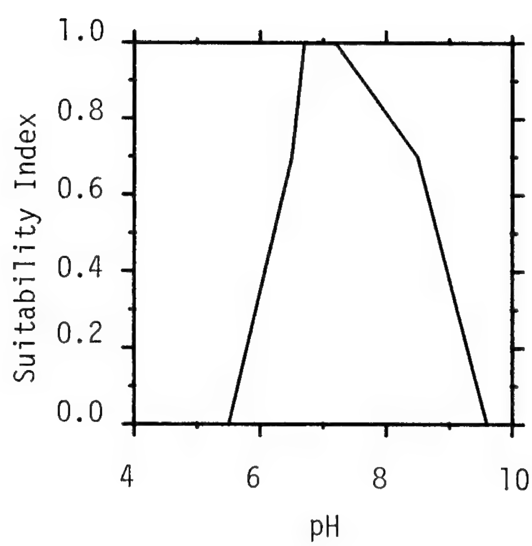
R,L (V$_6$) Maximum monthly average turbidity.



R (V$_7$) Average velocity at 0.6 m depth during average summer flow.



R,L (V$_8$) pH levels during the year.



Riverine Model

These equations utilize the life requisite approach and consist of three components: food-cover, water quality, and other.

Food-Cover (C_{F-C})

$$C_{F-C} = \frac{V_2 + V_6}{2}$$

Water Quality (C_{WQ})

$$C_{WQ} = (V_1^2 \times V_5^2 \times V_6^2 \times V_8)^{1/7}, \text{ or}$$

if V_1, V_5, or V_6 is ≤ 0.4, C_{WQ} equals the lowest of the following: V_1, V_5, V_6, or the above equation. If any variable equals 0, C_{WQ} equals 0.

Other (C_{OT})

$$C_{OT} = (V_3 \times V_4^2 \times V_7^2)^{1/5}, \text{ or}$$

if any of these variables is ≤ 0.4, C_{OT} equals the lowest of the following: V_3, V_4, V_7, or the above equation. If any variable equals 0, C_{OT} equals 0.

HSI determination

$$HSI = (C_{F-C} \times C_{WQ} \times C_{OT}^2)^{1/4}, \text{ or}$$

if C_{OT} or C_{WQ} is ≤ 0.4, then the HSI equals the lowest of C_{OT}, C_{WQ}, or the above equation.

Lacustrine Model

This equation utilizes the life requisite approach and consists of one component: water quality.

$$C_{WQ} = (V_1^2 \times V_5^2 \times V_6^2 \times V_8)^{1/7}, \text{ or}$$

if V_1, V_5, or V_6 is ≤ 0.4, C_{WQ} equals the lowest of the following: V_1, V_5, V_6, or the above equation.

HSI determination

$$HSI = C_{WQ}$$

If any variable equals 0, then $C_{WQ} = 0 = HSI$.

Sources of data and assumptions made in developing the suitability indices are presented in Table 1.

Sample data sets from which HSI's have been generated using the riverine HSI equations are given in Table 2. Similar data sets using the lacustrine HSI equation are given in Table 3. The data sets are not actual field measurements, but represent combinations that could occur in a riverine or lacustrine habitat. The HSI's calculated from the data reflect what we think carrying capacity trends would be in riverine and lacustrine habitats with the listed characteristics. Thus, the models meet the acceptance goal of producing an index between 0 and 1 which is believed to have a positive relationship to the habitat carrying capacity of slough darters.

Interpreting Model Outputs

The slough darter HSI determined by use of these models will not necessarily represent the population of slough darters in the study area. This may be due to the fact that these models rely on habitat-based factors, and other factors may more significantly affect the population level of slough darters in an area. If the model is a good representation of slough darter riverine or lacustrine habitat, then, in areas where slough darter population levels are due primarily to habitat related factors, the model should be positively correlated with long-term average population levels. However, this has not been tested. The proper interpretation of the HSI is one of comparison. If two habitats have different HSI's, the one with the higher HSI should have the potential to support more slough darters than the one with the lower HSI, given that the model assumptions have not been violated.

Table 1. Data sources and assumptions for slough darter suitability indices.

Variable	and source	Assumption
V_1	Hancock and Sublette 1958 Braasch and Smith 1967 Stroud 1967	D.O. levels which promote maximum growth and survival are optimum. Levels that are tolerated, but are not adequate for good growth are suboptimum. D.O. levels that may be lethal are unsuitable.
V_2	Hancock and Sublette 1958 Braasch and Smith 1967 Cross 1967	Since slough darters are found almost exclusively in pools, it is assumed that a high pool to riffle ratio would characterize optimum habitat.
V_3	Collette 1962	Stream gradients where slough darters are most often found are optimum. Gradients where the species is not found are unsuitable.
V_4	Wallen 1958 Collette 1962	The substrate type where slough darters are most often found is optimum. Substrate types where they are collected less often are suboptimum.
V_5	Hancock and Sublette 1958	Temperatures where slough darters are collected are assumed to be optimum.
V_6	Gerking 1945 Linder 1955 Wallen 1958 Blair 1959 Collette 1962 Braasch and Smith 1967 Pflieger 1975	Turbidity levels of waters where slough darters are typically found are optimum. Levels where the species is found less often or where food production may be limited is suboptimum.
V_7	Gerking 1945 Hanock and Sublette 1958 Wallen 1958 Blair 1959 Collette 1962 Braasch and Smith 1967 Cross 1967 Pflieger 1975	Average velocities where slough darters are most often collected are optimum. Velocities that the species does not tolerate are unsuitable.
V_8	Hancock and Sublette 1958 Stroud 1967 U.S. Environmental Protection Agency 1972	pH levels where slough darters are collected are optimum. Levels considered adequate for growth of freshwater fish have high suitability. Levels that provide only minimum protection or cause death for fish in general are unsuitable.

Table 2. Sample data sets using riverine HSI model.

Variable		Data set 1		Data set 2		Data set 3	
		Data	SI	Data	SI	Data	SI
Dissolved oxygen (mg/l)	V_1	5.0	1.0	3.0	0.4	6.0	1.0
% pool	V_2	45	0.9	30	0.6	75	1.0
Stream gradient (m/km)	V_3	1.5	0.2	1.2	0.5	0.2	1.0
Substrate type	V_4	C	0.5	B	0.6	A	1.0
Temperature (°C)	V_5	24	0.9	26	1.0	20.5	0.5
Turbidity (JTU)	V_6	25	0.7	100	1.0	40	0.9
Surface velocity (cm/sec)	V_7	10	0.9	15	0.6	2	1.0
pH	V_8	7	1.0	8.5	0.7	6.5	0.7
Component SI							
C_{F-C} =			0.80		0.80		0.95
C_{WQ} =			0.88		0.40		0.76
C_{OT} =			0.02		0.58		1.00
HSI =			0.02		0.57		0.92

Table 3. Sample data sets using lacustrine HSI model.

Variable		Data set 1		Data set 2		Data set 3	
		Data	SI	Data	SI	Data	SI
Dissolved oxygen (mg/l)	V_1	5.5	1.0	5.0	1.0	4.5	0.9
Temperature (°C)	V_5	22	0.7	20.5	0.5	24	0.9
Turbidity (JTU)	V_6	50	1.0	20	0.6	100	1.0
pH	V_8	8	0.8	6.5	0.7	9	0.4
Component SI							
C_{WQ} =			0.87		0.67		0.83
HSI =			0.87		0.67		0.83

ADDITIONAL HABITAT MODELS

Optimal riverine slough darter habitat is characterized by the following conditions, assuming water quality is adequate: moderate to highly turbid waters (50-150 JTU); sluggish or quiet waters (≤ 10 cm/sec); low average stream gradient (< 0.5 m/km); high pool to riffle ratio (> 50%); and a mud or silt substrate.

$$HSI = \frac{\text{number of above criteria present}}{5}$$

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15. Supplementary Notes

16. Abstract (Limit: 200 words)

A literature review encompassing habitat and species characteristics of the slough darter (Etheostoma gracile) is followed by a discussion of the relationship of habitat variables and life requisites of this species. These data are then incorporated into Habitat Suitability Index models for the slough darter.

This is one in a series of publications describing habitat requirements of selected fish and wildlife species. Numerous literature sources have been consulted in an effort to consolidate scientific data on species habitat relationships. These data have subsequently been synthesized into Habitat Suitability Index (HSI) models. The models are based on suitability indices formulated for variables found to affect the life cycle and survival of the species. The models are designed to be modified to evaluate specific habitat alterations using the HSI model building techniques presented in the U.S. Fish and Wildlife Service's Habitat Evaluation Procedures.

17. Document Analysis a. Descriptors

Habitability
Fishes

b. Identifiers/Open-Ended Terms

Habitat
Habitat Suitability Index
Slough darter
Etheostoma gracile

c. COSATI Field/Group

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(See ANSI-Z39.18) *See Instructions on Reverse* OPTIONAL FORM 272 (4-77) (Formerly NTIS-35) Department of Commerce

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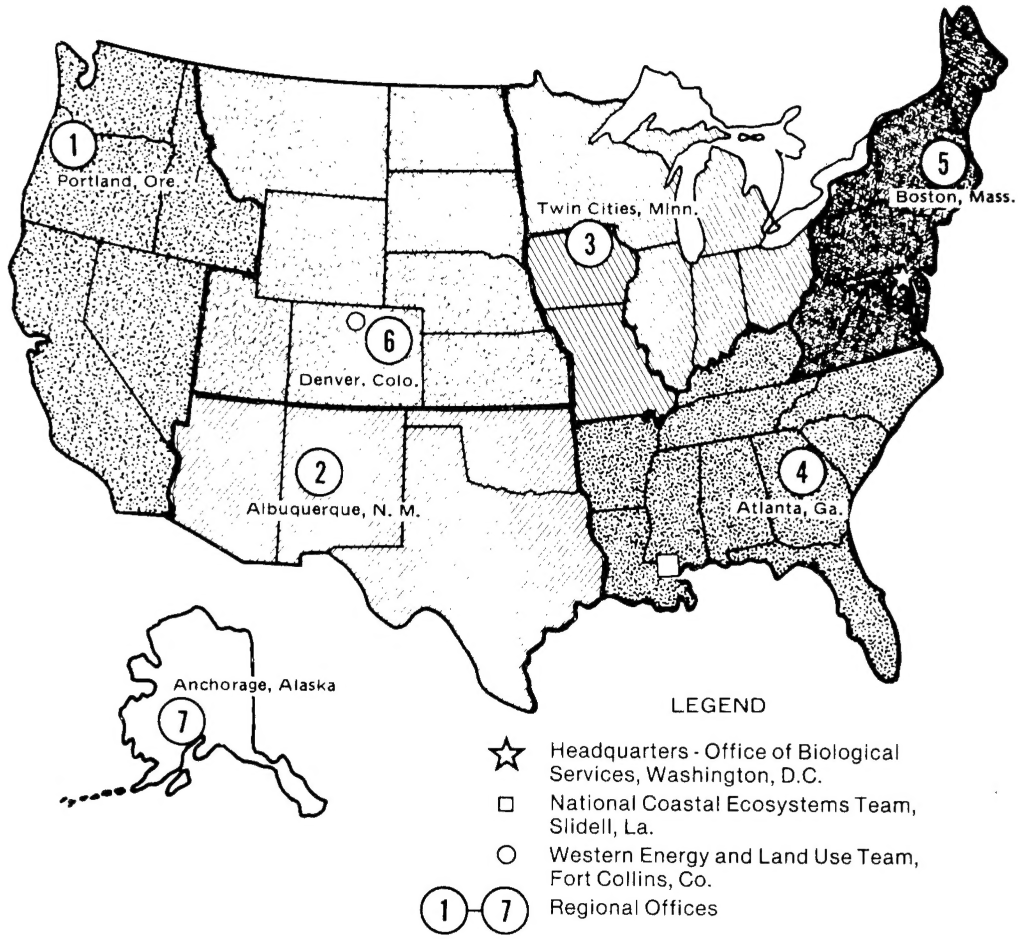

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